

SUSY HIGGS BOSONS AT THE LHC

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Recent results on MSSM Higgs physics at the LHC are reviewed. The dependence of the LHC discovery reach in the $b\bar{b}H/A, H/A \rightarrow \tau^+\tau^-$ channel on the underlying SUSY scenario is analysed. This is done by combining the latest results for the prospective CMS experimental sensitivities for an integrated luminosity of 30 or 60 fb^{-1} with state-of-the-art theoretical predictions of MSSM Higgs-boson properties. The results are interpreted in terms of the parameters governing the MSSM Higgs sector at lowest order, M_A and $\tan\beta$. While the higgsino mass parameter μ has a significant impact on the prospective discovery reach (and correspondingly the “LHC wedge” region), it is found that the discovery reach is rather stable with respect to variations of other supersymmetric parameters. Within the discovery region a determination of the masses of the heavy neutral Higgs bosons with an accuracy of 1–4% seems feasible. It is furthermore shown that Higgs-boson production in central exclusive diffractive channels can provide important information on the properties of the neutral MSSM Higgs bosons.

1 Introduction

Signatures of an extended Higgs sector would provide unique evidence for physics beyond the Standard Model (SM). While models with an extended Higgs sector often give rise to a relatively light SM-like Higgs boson over a large part of their parameter space, detecting heavy states of an extended Higgs sector and studying their properties will be of utmost importance for revealing the underlying physics.

2 Dependence of the LHC discovery reach on the SUSY scenario

In Ref. ¹ the reach of the CMS experiment with 30 or 60 fb^{-1} for the heavy neutral MSSM Higgs bosons has been analysed focusing on the channel $b\bar{b}H/A, H/A \rightarrow \tau^+\tau^-$ with the τ 's subsequently decaying to jets and/or leptons. The experimental analysis, yielding the number of events needed for a 5σ discovery (depending on the mass of the Higgs boson) was performed with full CMS detector simulation and reconstruction for the final states of di- τ -lepton decays ². The events for the signal and background processes were generated using PYTHIA ³. The experimental analysis has been combined with predictions for the Higgs-boson masses, production processes and decay channels obtained with the code **FeynHiggs** ⁴, taking into account all relevant higher-order corrections as well as possible decays of the heavy Higgs bosons into supersymmetric particles. The results have been interpreted in terms of the two parameters $\tan\beta$, the ratio of the vacuum expectation values of the two Higgs doublets of the MSSM, and M_A ,

the mass of the \mathcal{CP} -odd Higgs boson. The variation of the discovery contours in the M_A - $\tan\beta$ plane indicates the dependence of the “LHC wedge” region, i.e. the region in which only the light \mathcal{CP} -even MSSM Higgs boson can be detected at the LHC at the 5σ level, on the details of the supersymmetric theory. See Ref. ⁵ for previous analyses.

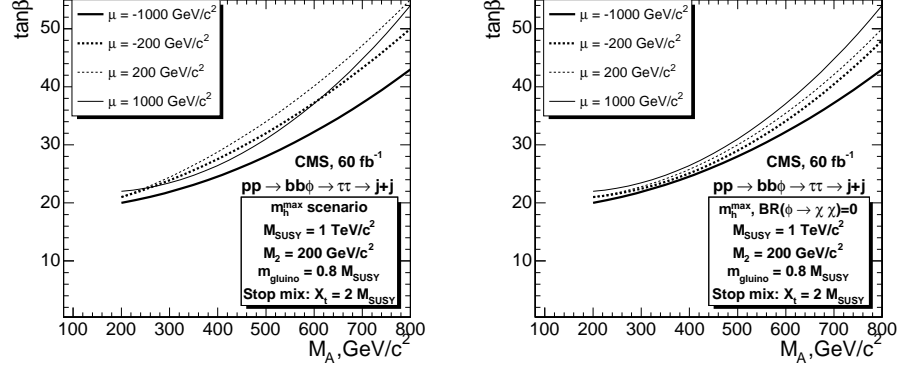


Figure 1: Variation of the 5σ discovery contours obtained from the channel $b\bar{b}\phi, \phi \rightarrow \tau^+\tau^- \rightarrow \text{jets}$ in the m_h^{\max} benchmark scenario for different values of μ (left plot). The right plot shows the result in the case where no decays of the heavy Higgs bosons into supersymmetric particles are taken into account.

Fig. 1 shows the variation of the 5σ discovery contours obtained from the channel $b\bar{b}\phi, \phi \rightarrow \tau^+\tau^- \rightarrow \text{jets}$ in the m_h^{\max} benchmark scenario⁶ for various values of the higgsino mass parameter μ . The parameter μ enters via higher-order corrections affecting in particular the bottom Yukawa coupling as well as via its kinematic effect in Higgs decays into charginos and neutralinos. Both effects can be seen in Fig. 1. While the left plot shows the full result, in the right plot no decays of the Higgs bosons into supersymmetric particles are taken into account, so that the right plot purely displays the effect of higher-order corrections. Comparison of the two plots shows that in the region of large $\tan\beta$ (corresponding to larger values of M_A on the discovery contours) the dominant effect arises from higher-order corrections. For lower values of $\tan\beta$, on the other hand, the modification of the Higgs branching ratio as a consequence of decays into supersymmetric particles yields the dominant effect on the 5σ discovery contours. The largest shift in the 5σ discovery contours amounts up to about $\Delta \tan\beta = 10$. The discovery contours have been shown to be rather stable with respect to the impact of other supersymmetric contributions¹.

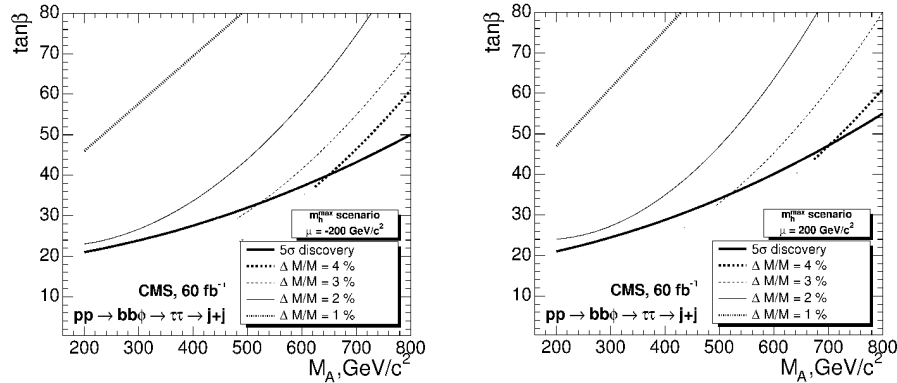


Figure 2: The statistical precision of the Higgs-boson mass measurement achievable from the channel $b\bar{b}\phi, \phi \rightarrow \tau^+\tau^- \rightarrow \text{jets}$ in the m_h^{\max} benchmark scenario for $\mu = -200$ GeV (left) and $\mu = +200$ GeV (right) is shown together with the 5σ discovery contour.

The prospective accuracy of the mass measurement of the heavy neutral MSSM Higgs bosons

in the channel $b\bar{b}H/A, H/A \rightarrow \tau^+\tau^-$ is analysed in Fig. 2. The statistical accuracy of the mass measurement has been evaluated via $\frac{\Delta M_\phi}{M_\phi} = \frac{R_{M_\phi}}{\sqrt{N_S}}$, where R_{M_ϕ} is the ratio of the di- τ mass resolution to the Higgs-boson mass, and N_S is the number of signal events ($\phi = H, A$). Fig. 2 shows that statistical experimental precisions of 1–4% are reachable within the discovery region. These results are not expected to considerably degrade if further uncertainties related to background effects and jet and missing E_T scales are taken into account. As discussed in Ref. ¹, a %-level precision of the mass measurements could in favourable regions of the MSSM parameter allow to experimentally resolve the signals of the two heavy MSSM Higgs bosons.

3 MSSM Higgs bosons in central exclusive diffractive production

Adding forward proton detectors to the CMS and ATLAS experiments (at 220 m and 420 m distance around them) can complement the standard LHC physics menu in an interesting way. In particular, “central exclusive diffractive” (CED) Higgs-boson production, where the outgoing protons remain intact and there is no hadronic activity between them, profits from an angular momentum selection rule ⁷ that permits a clean determination of the quantum numbers of the observed Higgs resonance which will be dominantly produced in a scalar state. Other important features of the CED Higgs-boson production process are a potentially excellent mass resolution (irrespective of the decay mode of the produced particle), a much better signal-to-background ratio than conventional Higgs search channels at the LHC, and the possibility to simultaneously access the $b\bar{b}$, WW and $\tau\tau$ decay modes of the Higgs boson(s).

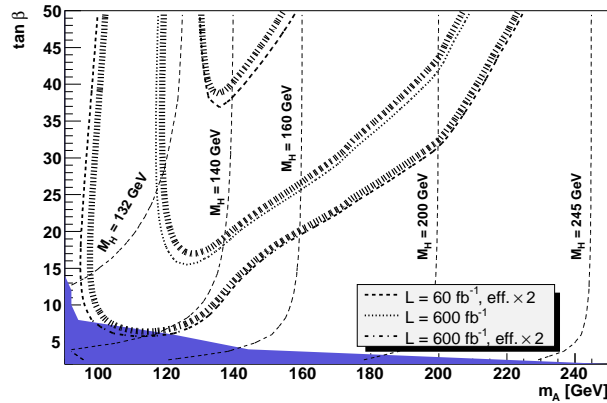


Figure 3: 5σ discovery contours for the $H \rightarrow b\bar{b}$ channel in CED production in the M_A – $\tan\beta$ plane of the MSSM. The prospective discovery reach is shown in the m_h^{\max} benchmark scenario (with $\mu = +200$ GeV). The results are shown for assumed effective luminosities (combining ATLAS and CMS) of 60 fb^{-1} , $60 \text{ fb}^{-1} \times 2$, 600 fb^{-1} and $600 \text{ fb}^{-1} \times 2$. The values of the mass of the heavy \mathcal{CP} -even Higgs boson, M_H , are indicated by contour lines. The dark shaded (blue) region corresponds to the parameter region that is excluded by the LEP Higgs searches in the channel $e^+e^- \rightarrow Z^* \rightarrow Zh, H$.

In Ref. ⁸ a detailed investigation of the prospects for the MSSM Higgs-boson channels $h, H \rightarrow b\bar{b}, \tau^+\tau^-, WW^*$ in CED production has been carried out (for other studies in the MSSM, see Ref. ⁹ and references therein). In CED the heavy \mathcal{CP} -even MSSM Higgs boson H can be produced and its decay into $b\bar{b}$ can be utilised. While in the SM the $\text{BR}(H \rightarrow b\bar{b})$ is strongly suppressed for $M_H \gtrsim 2M_W$ because of the dominant decay into gauge bosons, in the MSSM $H \rightarrow b\bar{b}$ remains by far the dominant decay mode also for larger masses as long as no decays into supersymmetric particles (or lighter Higgs bosons) are open. The CED Higgs-boson production in the $b\bar{b}$ channel is therefore important over a much larger mass range than in the SM. As an example, Fig. 3 shows the 5σ discovery contours for the $H \rightarrow b\bar{b}$ channel in CED production in

the M_A - $\tan\beta$ plane of the MSSM (using the m_h^{\max} benchmark scenario⁶) for different luminosity scenarios. It is found that the CED Higgs-boson production channel can cover an interesting part of the MSSM parameter space at the 5σ level if the CED channel can be utilised at high instantaneous luminosity (which requires in particular to bring pile-up background under control). For an effective luminosity of $600\text{ fb}^{-1}\times 2$ (see Ref.⁸) the discovery of a heavy \mathcal{CP} -even Higgs boson with a mass of about 140 GeV will be possible for all values of $\tan\beta$. This is of particular interest in view of the “wedge region” left uncovered by the conventional search channels for heavy MSSM Higgs bosons (see above). In the high- $\tan\beta$ region the discovery reach extends beyond $M_H = 200$ GeV at the $5\text{-}\sigma$ level. If the Higgs bosons h and/or H have been detected in the conventional search channels, a lower statistical significance may be sufficient for the CED production of h and H , corresponding to a larger coverage in the M_A - $\tan\beta$ plane. The CED Higgs-boson production channel will provide in this case important information on the Higgs-boson properties and may even allow a direct measurement of the Higgs-boson width⁸.

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